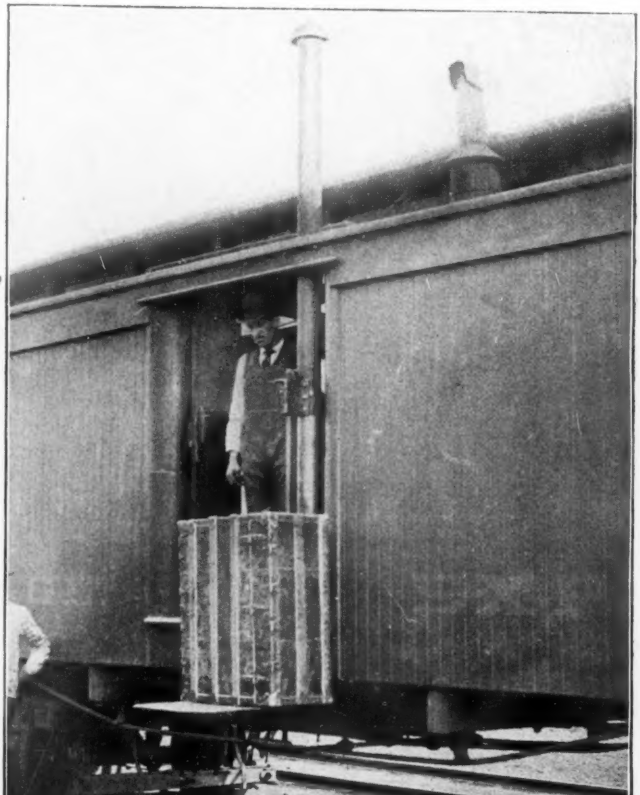
# Compressed Air

DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. III. NEW YORK, JANUARY, 1899. No. 11



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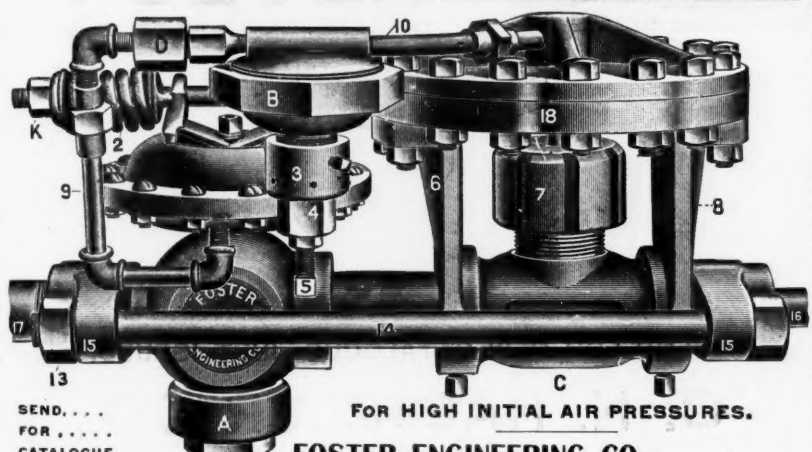


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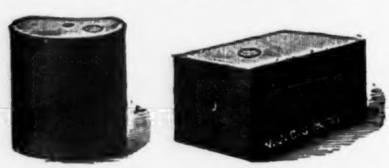

# Compressed Air.

A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

W. L. SAUNDERS, - - Editor and Proprietor
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We invite correspondence from engineers, contractors, inventors and others interested in compressed air.

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Those who fail to receive papers promptly will please notify us at once.

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VOL. III. JANUARY, 1899. NO. 11.

**Lehigh & Wilkesbarre Coal Co.**

Wilkesbarre, Pa., Nov. 18, 1898.

Gentlemen:

In reply to your inquiry relative to the use of compressed air for operating pumps, we beg to state that we have no trouble whatever to keep them from freezing, as we insert a small pipe, or jet, in the pump close to the valve and inject hot water or steam, which effectually prevents freezing. In the summer time we use water just as it comes from the reservoir. Trusting that this will be of service to you, we remain,

Yours very truly,
W. J. RICHARDS.
General Superintendent.

The foregoing letter was addressed to a manufacturer of air compressors and is published here because it is practical. At this season of the year when freezing is common and when so many people are using compressed air to run pumps, it is of interest to know how to prevent freezing in the exhaust. This is a subject which the readers of "Compressed Air" will recognize as rather prominent in our thoughts, because we know that compressed air has been "turned down" on many occasions because of the complaint that it gives trouble through freezing. As it is generally admitted that compressed air as a power is supreme in mines and as pumps are largely used in mines, it is natural that the miner should wish to operate his pumps by compressed air. He is doing this in many cases under disadvantages because of freezing. In the piston pump the chief trouble from freezing is usually in the exhaust, which is gradually choked by ice. Of course, the first thing to do is to provide a free exhaust for the pump which uses compressed air; by free exhaust we mean do not connect any pipes to it and have the exhaust as large as is practicable.

In England they advise bell-mouthing the exhaust, that is, inserting in the exhaust a fitting or pipe which is shaped like a bell. Our experience has taught us that it is best to insert nothing in the exhaust, but to have it as free and open as possible and to turn one's attention to preventing the accumulation of ice by either reheating the air before it enters the pump, or by inserting water or steam.

Reheating is obviously the best plan to follow, because it adds to the efficiency of the air by increasing its volume, due to expansion through heat. The objection to reheating in the mine is that the products of combustion are discharged in the mine and interfere with the ventilation. This is true only where the reheating is done on a large scale, but it is seldom necessary to reheat on a large scale, as what is wanted is simply an addition of 25 or 30 degrees of temperature, and if this is done properly it will require but a small quantity of fuel and will produce no more hurtful results than the burning of half a dozen miners' lamps.

If electricity is used in the mine it will serve a useful purpose by putting in resistance coils in contact with the air,

thereby heating it electrically. It costs, of course, more to heat electrically than to heat directly by fuel, but compressed air is sensitive to heat; a little heat adds largely to its volume, and when other conditions are considered, it is safe to say that reheating electrically pays.

A candle burning in a compressed air pipe will burn with greater intensity and will give off a larger heat effect than when burning in free air. The theoretically perfect reheater is that which burns a candle or some other substance within the air. A miner's lamp has been placed in a four inch pipe and has warmed a considerable volume of air. It is difficult, of course, to arrange an apparatus by which this form of reheating is made practical, but that some one will devise such an apparatus we have no doubt. There is no such thing as burning the air by internal reheating. The effect is simply to change the conditions by adding carbon and producing air and gas both of higher temperature, hence both more efficient when used as power.

External reheating, that is, simply applying heat to the external surfaces of vessels containing compressed air, is the commonest form of reheating, and may be used even in mines. Small reheaters are now furnished by builders of air compressors and are placed near the valve of the pump, these heaters being so arranged that the products of combustion are carried off, or in some cases they are simply discharged in the mine, but little fuel being required. These reheaters are sometimes arranged to burn gasoline and other oils. Where pumps are used without reheaters good results may be obtained by injecting water or steam on the plan mentioned in Mr. Richards' letter. Both water and steam carry a good deal of heat, that is, the specific heat is high compared with the specific heat of air, hence small quantities injected into the air directly at the valve or inlet serve a useful purpose in giving out heat and thus preventing freezing. It is not always, of course, convenient to get hot water and steam down into the mine at the point where the pump is located, but one may be surprised to know how far steam and hot water may be carried. If convenient, the pipe carrying the hot water or steam should be inserted within the compressed air pipe, so that the heat given off through condensation will be imparted to the compressed air. If the pump is too far away use cold water, for it is strange to say that even cold water will prevent freezing in pumps using compressed air; this is because the water gives off its heat to the air during expansion, and in addition to this it acts as a mechanical scourer in washing away the ice as it accumulates in the exhaust passages.

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## Recent Progress in the Development of Pneumatic Dispatch Tubes.*

By B. C. Bacheller.

As you all know, pneumatic dispatch tubes are not an invention of recent date; that is to say, their commercial application began forty-five years ago. Every one is more or less familiar with them, as they are used in large retail stores for the transmission of cash from the various counters to the cashier's desk. Many large office buildings are equipped with them for dispatching messages from one office to another. The Western Union Telegraph Company has used them since 1876 in New York City to transmit their telegrams from one office to another, it being found more expeditious than the telegraph.

The United States usually takes the lead in the application of mechanical devices, but in the uses of pneumatic dispatch tubes we are behind our European neighbors. London, Paris, Berlin and

—**Journal Franklin Institute.*

Vienna for years have had their pneumatic tube systems for transmitting telegrams between the central and branch post offices. The service is not confined to the large cities, for Liverpool, Brussels and other smaller cities are now equipped with this modern method of transportation.

There is much misconception of the size, capacity, length and use of the tube systems of Europe, for which the daily press is principally responsible. I have seen it stated that Paris and Berlin are connected by pneumatic tubes. It goes without saying that such a statement is untrue. Many people believe that mail is sent through the tubes, but that is also untrue, for the tubes are not large enough for that purpose. They are used only for the transportation of telegrams and messages. The largest tubes in London are only 3 ins. in diameter, while those of Paris and Berlin are about 2¼ ins. Fig. 7 shows the Berlin and London carriers.

The first tube was laid in London in 1853 by the Electric International Telegraph Company, under the direction of Mr. Josiah Latimer Clark. It was 1½ ins. in diameter, and extended from Founder's Court to the Stock Exchange, a distance of 220 yards. Year by year the system has been extended, until now the entire business section of the city is covered by the nework of tubes radiating from the General Post Office and terminating in the numerous sub-Post Offices. (In England the telegraph is controlled by the Government, and the telegraph offices are in the post offices.) The tubes are of lead, encased in cast iron and laid in pairs for dispatching in opposite directions. Berlin has a similar system to that of London, but in Paris the tubes are laid in circuits with several stations on a circuit. The carriers are forwarded in trains from one station to another around the circuit.

It is not the purpose of this paper to describe these European systems in detail, but I refer to them to give some idea of the state of the art up to 1893.

Admitting that the European cities have gotten the start of us in point of time, we are bound not to be beaten in the end. While they continue to operate their small 2- and 3-inch tubes for telegrams only, we begin by building 6-inch, and use them to transport mail

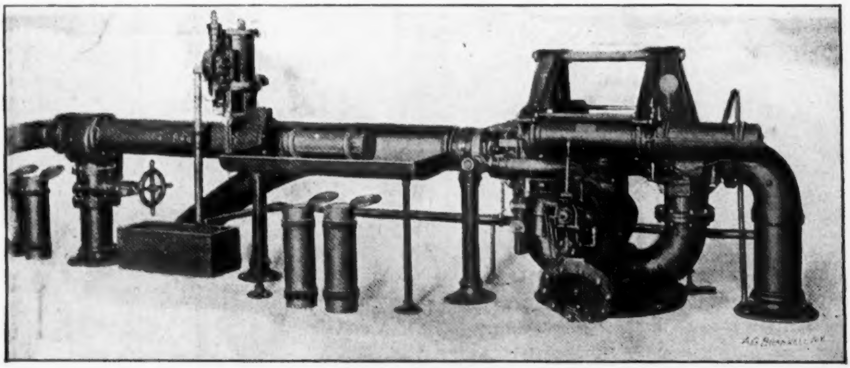

FIG. 1.—SENDING APPARATUS AND OPEN RECEIVER, PRODUCE EXCHANGE LINE, MAIN POST OFFICE, NEW YORK CITY.

in large quantities, and the beginning was made in the city of Philadelphia five years ago, when the first line was opened by the Hon. John Wanamaker, then Postmaster-General.

It may seem to many of you like a simple step, from 3-inch to 6-inch tubes, but I will say from experience that the small tubes were no guide or help to us in building larger ones. The methods of operation and apparatus used with the small tubes could not be applied to the larger. The principal reason for this lies in the greatly increased weight of the cartridge, or, as we term it, carrier, that is dispatched through the tube. The weight causes friction against the walls of the tube and is a storehouse for energy that

must be taken care of when the carrier is brought to rest. A heavy carrier is like a heavy train on a railway. The carriers used in the small tubes are stopped by allowing them to strike some solid object, which can be done without injury to them, but the large carriers used in 6- and 8-inch tubes must be brought to rest gradually by means of an air cushion, and this involves the use of automatic receiving apparatus not required in the small tubes. The more important problems that had to be solved in designing the system of 6-inch tubes were the sending apparatus, the receiving apparatus, the carrier and the tubes. This was for a line of two stations. When intermediate stations are used the problems of switches and automatic receiving apparatus to select carriers at their destined stations had to be met.

The first double line of tubes built in Philadelphia was laid from the main Post-office, Ninth and Chestnut Streets, along Chestnut Street to the sub-Post-office. now located in the Bourse, a distance of about 3,000 feet. The tubes were made of cast-iron water pipe, bored upon the interior to an exact diameter of 6⅛ inches. The lengths were joined together by making a counter bore at the bottom of the bells, into which the machined end of the adjoining length fitted, and filling the bell with yarn and lead caulked in the usual manner.

Where it became necessary to turn corners seamless brass tubing was used, bent to a radius of not less than 6 feet. The tubes were simply buried in the ground, one above the other, at a depth varying from 3 to 10 feet, depending upon the location of other underground construction, such as water and gas pipes, conduits, sewers, etc.

The line was, and still is, operated by an air compressor located in the basement of the main Post-office. This compressor is of the duplex type, built by the Clayton Air Compressor Works, and does not differ, except in relative size of cylinders, from the compressors on the market for general purposes. It develops about 25 horse-power and compresses about 800 cubic feet of free air per minute to a pressure of 7 pounds per square inch. The dispatching and receiving apparatus is located on the main floor of the Post-office near the cancelling machines, and in the

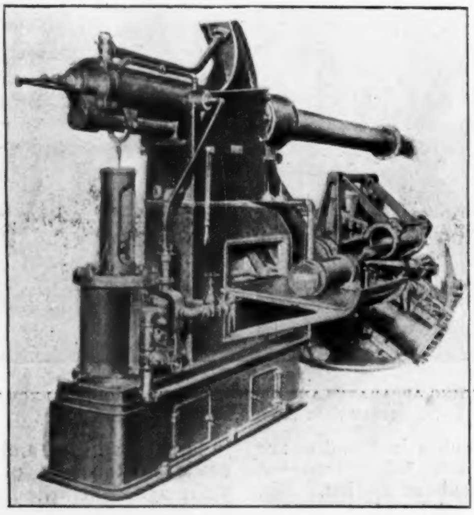

FIG. 2—SENDING APPARATUS AND CLOSED RECEIVER, PRODUCE EXCHANGE LINE, POSTAL STATION H, NEW YORK CITY.

rear room of the sub-Post-office in the basement of the Bourse.

The tubes are in operation from nine o'clock in the morning until seven in the evening, excepting the noon hour.

The air current flows continuously from the main Post-office to the Bourse through one tube and returns to the main Post-office through the other, thus forming a loop with the return end connected to the suction pipe of the compressor at the Post-office. There is an opening in the tube to the atmosphere near where it is connected to the compressor, so that the entire circuit contains air at a pressure above the atmosphere.

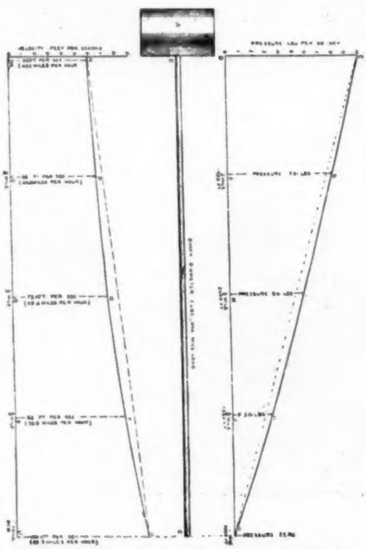

FIG. 3.—DIAGRAM SHOWING THE PRESSURE AND VELOCITY OF THE AIR IN A PNEUMATIC TUBE.

It is a pressure system rather than a vacuum system, as these terms are commonly understood.

Carriers occupy sixty seconds in transit from the Post-office to the Bourse and fifty-five seconds for the return trip. They can be dispatched at six-second intervals, or ten per minute in each direction.

This 6-inch tube has been in operation for five years and is doing good service to-day.

Not content with this the promoters of this enterprise decided to go one step further and build an 8-inch tube.

The second line was laid in New York City between the main Post-office and branch Post-office P, in the Produce Exchange Building. It is similar in method of operation to the first Philadelphia line, but somewhat longer, the distance between stations being about 4,000 feet. Some improvements were made in the sending apparatus, utilizing the air pressure to do what was formerly done by manual labor. See Figs. 1 and 2.

When this Produce Exchange circuit was opened for business the construction of a second circuit was well under way in New York, extending from the main post office to branch post office H, on Forty-fourth Street, near the Grand Central Depot, a distance of 3½ miles, with three intermediate stations on the line; at Postal Station D, Third Avenue and Eighth Street; Madison Square Postal Station, and Postal Station F, at Third Avenue and Twenty-eighth street.

The main line of this circuit was opened February 11, but the receiving apparatus for the intermediate stations is not yet completed. This is the longest circuit built thus far. The inside diameter of the tubes, like the Produce Exchange circuit, is 8⅛ inches. There are two tubes, one for dispatching up-town and the other down-town. They are operated by air compressors, located one at the post office and the other at Forty-fourth Street. The time of transit of the carriers in either direction is about seven minutes. The air pressure at the compressors is 13 lbs.

During the Autumn of last year a circuit of 8-in. tubes was constructed in Boston between the main post office and the North Union Railway Station, a distance of about 4,500 feet, or a little less than 1 mile. This is similar in all respects to the Produce Exchange line in New York. It is used to transport the outgoing mail from the post offices to the trains, and the incoming mail from the trains to the post office.

On Thursday, April 7, a circuit of tubes between the main post office and the Pennsylvania Railroad Station at Broad Street, in Philadelphia, was formally opened for the transportation of mail to and from trains. Since then an intermediate station has been established at the Reading Terminal. The tubes are laid from the post office through Chant Street to Tenth Street, up Tenth Street to Filbert Street, and out Filbert Street to the Pennsylvania station.

Another circuit has been constructed between the main post office in New York and the main post office in Brooklyn, by way of Brooklyn Bridge.

The total length of 8-in. tubing in all these circuits is a little more than 17 miles. This has all been manufactured and laid under ground since August 1, last year.

## Theory.

A current of air may be made to flow through a tube by either pumping the air in at one end under a pressure above that of the atmosphere, or by exhausting the air, thereby reducing its pressure below that of the atmosphere. In either case it is the difference of pressure at the two ends of the tube that causes the air to flow. Both methods are used in operating the London and Paris tubes, and both are used in the cash systems of our large retail stores, but all of our large tubes are operated by compressing the air so that the air-pressure in the tubes is at all points above that of the atmosphere. The determining of which system shall be adopted depends largely upon circumstances.

In the operation of short lines of tubes all of the machinery and apparatus can be concentrated at one point by using compressed air in the outgoing tubes and rarified air in the incoming tubes.

So far as power is concerned, the exhaust method is more economical, because nearly all the power is consumed in overcoming the friction of the air in the tube, and this friction varies directly with the density of the air.

There are several reasons why the compressed-air method of operation is better: first, if there are any leaks in the tubes and they happen to be laid in the wet ground, water will be drawn in when the air is exhausted, while it will be kept out if the air pressure is above the atmospheric; second, air cushions, for checking the speed of the carriers when they arrive at a station, are much more efficient and effective with compressed air than with rarefied air; third, cylinders and pistons used to operate sending and receiving apparatus can be made smaller when compressed air is used.

There are two methods of using the current of compressed or rarefied air in the operation of a line, and these are termed the intermittent and constant methods. The first consists in storing compressed air in a suitable tank, or by exhausting the air from a tank; then when we wish to dispatch a carrier we place it in the tube and connect the tube with the tank by opening a valve. As soon as the carrier arrives at the distant end of the tube the valve is closed and the air soon ceases to flow. When a long interval of time elapses between the dispatching of carriers, this is the most economical method of operation; but if carriers have to be dispatched frequently, a great deal of time would be lost in starting and stopping the air current throughout the whole length of the tube. Under these conditions the second method, which consists in maintaining a constant current of air in the tube, and in having the carriers inserted

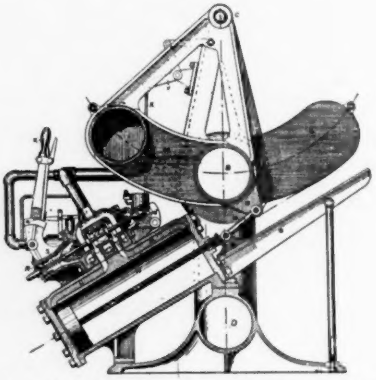

FIG. 4.—CROSS-SECTION OF SENDING APPARATUS

and ejected at the ends of the tube without stopping the current of air for any appreciable length of time, is much more rapid and efficient. This latter method is the one used in the operation of all our large tubes. The current of air flows continuously all day, and the carriers containing mail are swept along like boats in a rapidly flowing stream. The analogy is quite perfect. The boats obstruct the flow of water and check its speed but little. In order to compute the speed with which the boats will pass from one point to another, we have only to know the speed of the stream between those points when no boat is in it. The presence of the boats does not change the speed ap-

preciably. So it is with carriers in a pneumatic tube; the air flows nearly as rapidly when a carrier is in a tube as when there is none. The friction of the carrier against the inner surface of the tube creates a slight drag, but it checks the speed of the air only a little. Therefore, in order to know the speed with which a carrier will be transported from one station to another, we need only to know the velocity with which the air flows through the tube when no carrier is present.

Let us assume a simple case of an 8-inch tube one mile long, connected at one end to a tank in which a constant air pressure of 10 pounds per square inch is maintained, the other end of the tube being opened to the atmosphere.

I have constructed a diagram showing the air pressure at all points along the tube (see Fig. 3). The abscissæ represent lengths of tube in feet and the ordinates air pressure above the atmospheric in pounds per square inch. At the tank end the pressure is 10 pounds, at the open end zero, and at the quarter, half and three-quarter mile points 7.91, 5.61 and 3.01 lbs. respectively. It will be observed that the pressure curve is slightly convex upwards. This is due to the expansion of the air in the tube. The pressure curve of the flow of water in a pipe is a straight line. The fall of pressure along the tube is analagous to the fall of level in a flowing stream or to the fall of potential along a wire in which a current of electricity is flowing.

I have constructed another diagram showing the velocity of the air at every point along the tube. The abscissae are lengths of tube in feet, the ordinates velocity of the air in feet per second. The velocity at the tank end, quarter, half and three-quarter mile points and at the opened end is 59.5, 65, 72, 83 and 100.4 feet per second, respectively. It will be noticed that the velocity of the air increases as it flows along the tube, and that it increases more rapidly as it approaches the open end of the tube. The increase of velocity is due to the expansion of the air as it flows along the tube, and the expansion results from the fall of pressure. The mean of all the ordinates gives us the mean velocity, which enables us to compute the time of transit of a carrier through the tube. We can also determine from this velocity curve the time of transit between any two points on the tube which may represent stations.

From the velocity with which the air is discharged from the open end of the tube we compute the quantity of air that must be compressed per minute. The quantity of free air and the initial pressure enables us to compute the horse-power required to maintain the current of air constantly flowing. Of course, there are numerous factors which enter into these computations which are only determined by experiments and experience, such, for example, as the quantity of air that escapes from the tube at the sending and receiving apparatus; the fall of pressure of the

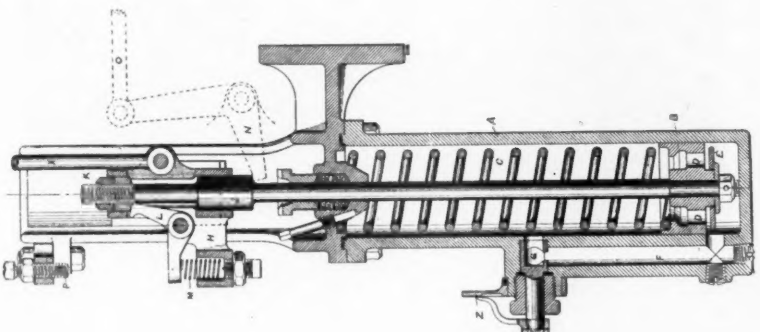

FIG. 5.—TIME-LOCK FOR SENDING APPARATUS.

air in flowing around bends and through the apparatus; the efficiency of the air compressor, etc.

The temperature of the air, from the instant it enters the compressor until it is discharged at the open end of the tube, is an interesting and important factor in the theory of pneumatic transmission. Since pressures above 25 lbs. per square inch are seldom used, the air cylinders of the compressors are not water-jacketed, hence the air is heated by compression to a temperature found by measurement to be above the theroretical amount that we should expect from thermodynamic formulae. The reason for this will be understood when we remember that the incoming air is heated by contact with the hot walls of the cylinder. When air is compressed to 7 lbs. per square inch, it leaves the compressing cylinder at about 160 degs. F. We should expect much of this heat to be soon lost by conduction and radiation through the walls of the tube, and as the air flows through the tube, constantly expanding, it would not be unreasonable to expect considerable reduction in temperature by the time it reached the open end of the tube—a temperature considerably below that of the atmosphere. Experience teaches us that after leaving the compressor the temperature of the air falls rapidly, and that the temperature in the tubes underground is almost constant, being about that of the surrounding earth. The compression may be considered as adiabatic and the expansion as isothermal with a small error.

The atmosphere at all times contains more or less moisture in a state of vapor, and its capacity for water vapor varies directly with its temperature; that is to say, the higher the temperature the more water vapor will the air contain, and vice versa. The temperature of the air in the tubes is frequently and usually lower than the atmosphere out-of-doors, consequently it often happens that moisture is deposited upon the interior of the tubes. The quantity is never very great, but sometimes the carriers come out of the tube coated upon the exterior with a thin film of moisture. We use the same air over and over, thereby avoiding drawing into the tube large quantities of moisture-laden air.

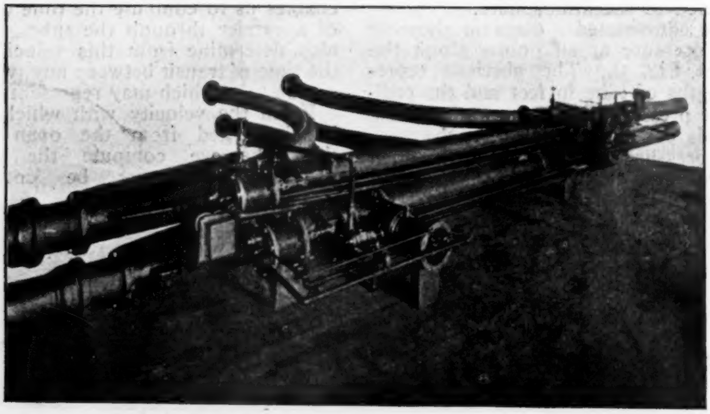

FIG. 6.—SET OF CUT-OUT SWITCHES FOR EIGHT-INCH PNEUMATIC TUBES.

Having thus briefly discussed the theory of the flow of air in long tubes, we will now consider some of the necessary mechanical details. Keeping in mind our 8-in. tube, 1 mile long, connected to a tank of compressed air at one end and open to the atmosphere at the other, thereby maintaining a constant flow of air through the tube. In order to utilize this tube and air current for the transportation of mail or merchandise, we must have some means

of inserting carriers containing the material to be transported into the tube, without the escape of air. In other words, we must have some form of sending apparatus or transmitter. This might be accomplished by having a section of the tube with valves at each end to stop the flow through this section and conduct it through a by-pass. A carrier could then be inserted into this section of tube and the valves be turned to their normal position. Or, what we find to be more practical is to have a section of the tube that can be swung out of line with the main tube to receive a carrier and then swung back into line again. This is the form of sending apparatus that we use in all our 8-inch tubes. The section of tube is swung by a cylinder and piston operated by the air pressure taken from the tube (see Figs. 1 and 4). The attendant has only to place a carrier in the sending apparatus and pull a lever. By using two swinging sections of tube, one of which is always in line with the main tube, the apparatus is ready at all times to receive a carrier.

In connection with the sending apparatus, a time lock is used to measure and determine the time interval between the dispatching of carriers; in other words, to prevent carriers being dispatched too frequently. The period varies from six to fifteen seconds, depending upon the length of the line. The time lock is found necessary to prevent the collision of carriers and to give the receiving apparatus time to operate. The time lock consists of a dash-pot filled with oil and arranged to lock the sending apparatus, except when the piston of the dash-pot is at the bottom of its cylinder (see Fig. 5).

If our receiving station be located at the open end of the tube, then we must have some form of receiving apparatus to stop the carriers without shock when they arrive. For this purpose we have in our system what we term an open receiver. It consists of a section of tube about 4 feet long, closed at one end by a sluice gate and attached to the end of the main line. The air flows out through slots in the tube just before it reaches the receiver. When a carrier arrives it runs into this closed section of tube which forms an air cushion. The compression of the air by the stoppage of the carrier serves to operate a small valve, which causes the sluice gate to be raised by a cylinder and piston located above it. When the gate raises the carrier is forced out on to a receiving table, the pressure in the tube

FIG. 7.—(1) Carrier used in the Berlin system; (2) Largest carrier used in the London system; (3) Six-inch carrier used in the first Philadelphia system; (4) Eight-inch carrier used in New York and Boston.

being just sufficient to do this. The gate is automatically closed after the carrier has been discharged (see Fig. 1).

If our receiving station be located at any other point on the line of the tube we cannot use this form of open receiver, for the pressure in the tube is so high, as shown on the diagram, that the air would escape with great force, hence we must use what we term a closed receiver, consisting of a section of tube forming a receiving chamber and air cushion that can be placed in line with the main tube to receive the carrier, and then moved out of line with the main tube to discharge the carrier, the end of the main tube being closed during this displacement. The

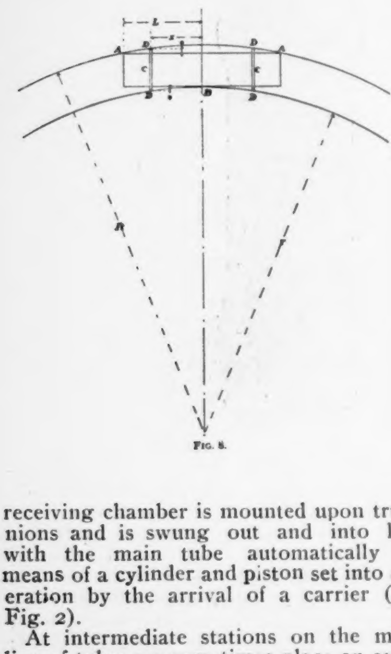

FIG. 8.

receiving chamber is mounted upon trunnions and is swung out and into line with the main tube automatically by means of a cylinder and piston set into operation by the arrival of a carrier (see Fig. 2).

At intermediate stations on the main line of tubes we sometimes place an automatic receiving apparatus that will stop all carriers passing through the tube, and discharge those intended for that station, while all others are sent on in the tube. This is accomplished by placing various sized metal discs upon the front end of the carriers and having electric contact points at each of the stations set at graduated distances apart to correspond with the sizes of discs on the ends of the carrier. When a carrier arrives at a station where its disc is of the proper diameter to span the distance between the contact points, and thereby close the electric circuit, then that carrier will be discharged from the tube; but if the disc is too small to span the distance between the contact points, then the carrier will pass on in the tube to the next station, and so on.

Intermediate stations are usually supplied with cut-out switches, so that carriers can be sent directly past the station without entering it. These switches are moved by air pressure, controlled electrically from the nearest station (see Fig. 6).

There is no part of this system that has been the object of more thought and study than the carrier that contains the mail or other material to be transported. It is made of a seamless steel tube 23½ inches long, closed at the front end by a sheet metal head and buffer, and closed at the rear end by a hinged cover provided with a lock (see Fig. 7).

The body of the carrier is about an inch smaller than the tube through which it travels, the space between the body of the carrier and the surface of the tube being filled by two fibrous rings that serve not only to prevent the escape of air past the carrier, but as wearing surfaces to slide on the lower side of the tube. These bearing rings are made of cotton fiber, and they will endure until the carrier has traveled about 5,000 miles, when they become worn so small that they have to be replaced by new ones. A carrier weighs 13¾ pounds and will contain 600 ordinary letters.

The tubes used in all the circuits thus far constructed are of cast iron bored accurately upon the interior, except bends, which are made of seamless brass tube. The iron tube is cast in 12-foot lengths, with a bell upon one end similar to gas and water pipes. A counter bore is turned in the bottom of each bell, into which the machined end of the adjoining length fits closely. The joints are made by yarn and lead caulked in the usual manner.

Where short bends have to be made in the tube for the purpose of turning corners in the streets, entering buildings, etc., brass tubing is used bent to a radius of twelve times the diameter of the tube, or a radius of 8 feet for an 8-inch tube. A uniform radius is always used, for it facilitates manufacture.

In order to maintain a uniform and circular cross-section of the tubes during the process of bending they are filled with resin.

The location of the bearing rings on the body of a carrier also has an important relation to the bends in order to give a carrier of maximum capacity. Having determined the length and diameter of the carrier body, we place the bearing rings not on the ends, but at a point where, in passing through a bend of minimum radius, the corners and center of the carrier and the bearing rings will touch the walls of the tube at the same time. This can best be explained by referring to Fig. 8. The rings C C are so placed that in passing through the bend the ends of the carrier touch the outer circumference of the tube at A A, at the same time that the body of the carrier touches the inner circumference at B, and the rings touch both inner and outer circumferences at D D D D.

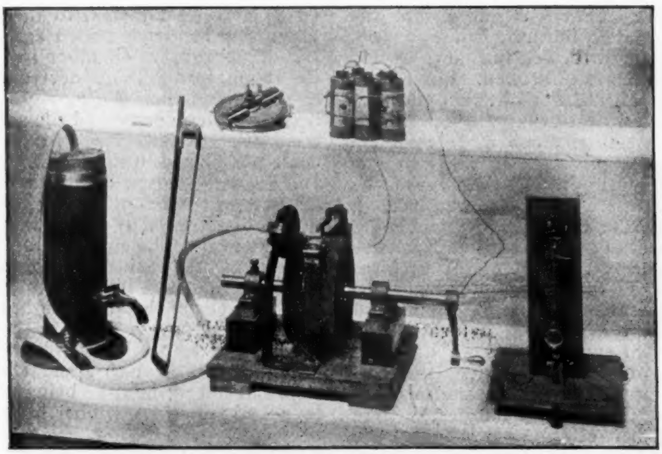

FIG. 9.—CHRONOGRAPH USED IN PHILADELPHIA FOR LOCATING OBSTRUCTIONS IN PNEUMATIC TUBES.

To manufacture the tubes, brass bends, carriers, sending and receiving and other apparatus used in the system, a factory has been erected at Tioga and Memphis Streets, Philadelphia. Much of the machinery used in the various processes of manufacture has been especially designed for the purpose, and most noteworthy, perhaps, are the machines for boring the cast iron tubes. The tubes are bored in a vertical position, for two reasons: (1) It economizes space; (2) the chips fall away from the cutters.

The boring machines are placed upon galleries about 11 feet above the floor. The bell ends of the tubes are clamped to the machines and rest on a pedestal on the floor below. The boring is done by six cutters attached to a head that is mounted on the lower end of a vertical boring bar. The bar is revolved by gearing and fed downward by a screw attached to the cutter head and extended downward through the center of the tube being bored. The feed screw does not revolve, but is drawn downward by a nut attached to the pedestal on which the tube is supported. The nut is revolved by gearing and a rope belt driven from the machine above. When a tube is placed in the boring machine the feed screw is pulled up through it and attached to the cutter head. The boring bar simply serves to revolve the cutter head and not to guide it. The cutter head is guided by four hardwood blocks that fit the finished bore of the tube closely. The pull of the feed screw also helps to keep the cutter head in place. The cutters are flat pieces of steel, with a cutting edge at 45 degrees with the axis of the tube. The angle of the cutter tends to make the cutter head

follow the core of the tube. After the bore is finished another head is attached to the bar, which makes the counter bore at the bottom of the bell.

A special machine has been designed for bending the brass tubes, consisting of three rolls, one of which is adjustable. This operation of bending is one that requires much experience and skill on the part of the operator.

*Locating Obstructions.*—You will, perhaps, be interested in an experiment that we made in Philadelphia two years ago to locate a carrier that became lodged in one of the tubes.

The Philadelphia line was laid in the Winter season, and before the trench was back-fllled the loose earth became frozen and we were obliged to put it into the trench in that condition; consequently, when the ground thawed the tubes settled and one of them was broken. For a long time this break did not obstruct the passage of carriers, but eventually one of the broken ends settled down more than the other and caught one of the carriers, blocking the entire line. We had no means of knowing where the break was located, and to excavate the entire distance between the stations involved great expense and annoyance. I made several attempts to locate it by the fall of pressure, etc., but was not satisfied with the results, so decided to try a method of locating by the velocity of sound.

The plan was to disconnect the terminal apparatus at one of the stations, fire a pistol into the tube, and note the time that elapsed between the discharge of the pistol and the return of the sound as an echo reflected back from the obstructing carrier; then, knowing the velocity of sound, a simple calculation would give us the distance from the station to the carrier.

I had a rough chronograph constructed, using a pulley for a drum, mounted upon a horizontal shaft with a crank for rotation and a screw to give longitudinal motion (see Fig. 9). Time was measured by the beats of a clock pendulum, recorded on the chronograph drum by a stylus which moved under the pull of an electro-magnet at each beat of the pendulum. The pendulum was arranged to close an electric circuit in the usual manner by swinging through a globule of mercury. In addition to the clock a tuning fork was used to measure time by the number of waves traced on the smoked surface of the drum. For the measurement of small fractions of a second the tuning fork is more accurate and convenient than a clock, but when the period extends over several seconds the work of counting thousands of small waves becomes very laborious.

I selected a fork tuned to 512 vibrations per second, which enabled me to measure to 1-1000 of a second with a small error. In fact, with a little care it was possible to measure to 1-5,000 of a second.

The fork was arranged in a horizontal position, having a horse hair cemented to one prong, which traced a sinuous line on the drum as the latter was turned. The sound of the pistol discharge was recorded by a stylus attached to the end of an aluminum arm that rested against a rubber diaphragm. A chamber in the rear of the diaphragm was connected to the end of the pneumatic tube by a piece of rubber hose which conveyed the sound waves from the tube to the chronograph. A cock was placed in the middle of the hose and partially closed before the pistol was discharged to prevent too great distention of the diaphragm by direct impact of the sound waves. The cock was opened by an attendant after each discharge and before the echo returned, in order that the feeble sound waves of the echo might not fail to be recorded.

The muzzle of the pistol was inserted into the tube through a small hole in the side, the end of the tube being closed by a funnel to which the rubber hose was connected.

When the apparatus was properly adjusted a measurement was taken in the following manner: The clock was started, the tuning fork set in vibration by striking with a mallet or by bowing, and the drum rotated by hand; then the pistol was discharged and the cock in the rubber hose opened. A few moments only were required to count the waves of the tuning fork and from them compute the time.

The experiments were usually repeated several times to eliminate errors. Five experiments gave the following results:

| | | |
|---|---|---|
| 1.................. | 2·791 | seconds. |
| 2.................. | 2·794 | " |
| 3.................. | 2·793 | " |
| 4.................. | 2·793 | " |
| 5.................. | 2·794 | " |
| Mean............ | 2·793 | " |

A thermometer was placed in the ground beside the pipe and the temperature found to be 39 degrees. It was assumed that this was the temperature of the air in the tube. The velocity of sound at 32 degrees was assumed to be 1,093 feet per second, and the increase of velocity for each degree of temperature to be 1.12 feet; this gives at 39 degrees the velocity of 1,101 feet per second.

In 2.793 seconds the sound would travel 3,075 feet, which locates the carrier at 1,537 feet from the instrument. This indicated that the carrier was lodged 100 feet east of Seventh Street, and workmen were ordered to excavate at that point. Before reaching the tube air was heard escaping from the break, and the carrier was found almost exactly where it had been located by the instrument.

It is impossible to say what the limits of the method are so far as distance is concerned, but experiments of Regnault show that the report of a pistol is no longer heard at a distance of—

1,159 metres in a tube 0·018 m. in diameter.
3,810 " " " 0·300 " "
9,540 " " " 1·100 " "

But the same sound waves will vibrate a senstive diaphragm at distances of 4,156, 11,430 and 19,851 metres respectively.

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## Driving Pumps by Compressed Air.

By William Cox.

"Compressed air may be, and should be, much more extensively used than it has been hitherto for operating pumps."

It must not be supposed, however, that any common steam pump, having attached to it a pipe supplying air under any hap-hazard pressure will perform satisfactory service. To insure such various details relating to the manifold operations to be performed must be carefully considered and duly taken into account, so that from the variety of conditions presented, a harmonious whole may be evolved. And even then, when the installation, if it may be dignified by such a term, has been made with judgment and due regard to the exigencies of the case, high economy must not be looked for or expected, as the common direct-acting pump, no matter how driven, is and will ever be a waste producer. Taking the pumps, however, as they are generally met with, the object of this paper is to present in as simple a manner as possible the conditions which must be fulfilled, so that with the material at hand, or easily secured, the best results may be obtained.

In what follows the following nomenclature is observed throughout:

$D_s$ or $D_a$ = Diameter of steam or air cylinder in inches,
$d$ = Diameter of water cylinder in inches,
$l$ = Length of stroke in inches,
$n$ = Number of single strokes per minute,
$p_s$ = Piston speed in feet per minute, $= \frac{l \times n}{12}$
$E$ = Useful effect, efficiency or corrected capacity,
$G$ = Gallons of water required to be discharged per minute, (U. S. Gallons of 231 cub. ins.),
$P$ = Gauge Pressure of the air in pounds per sq. in.,
$V$ = Equivalent volume of free air required,
$h$ = Head in feet to which the water is to be pumped,
$p$ = Resistance per square inch on the pump piston $= 0·433\ h$.

The first point which presents itself for our consideration is the quantity of water that is required to be handled, with the corresponding necessary diameter of the water cylinder of the pump, so as to secure good results in this part of the system. The formula giving the theoretic discharge of any pump cylinder is:

$$G = \frac{0·7854 d^2 \times l \times n}{231} = 0·0034 d^2 \times l \times n = 0·0408 d^2 \times p_s \quad \text{..........(1)}$$

By transposition we have

$$d^2 = \frac{G}{0·0408\, p_s} \text{ whence}$$

$$d = 4·95 \sqrt{\frac{G}{p_s}} \quad \text{..........(2)}$$

and allowing for a piston speed of 100 feet

per minute, which is very commonly assumed as reasonable, we have:

$$d = 0{\cdot}495\sqrt{G} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The following table, calculated from Eq. (1), gives the theoretical discharge of water cylinders of various diameters, in gallons per minute, the piston speed being assumed throughout as being 100 feet per minute:

TABLE I.

| Diam'r of Water Cylinder. | Discharge. | Diam'r of Water Cylinder. | Discharge. |
|---|---|---|---|
| 2 inches. | 16·32 c. ft. | 9½ inch's. | 368 22 c. ft. |
| 2½ " | 25·50 " | 10 " | 408·00 " |
| 3 " | 36·72 " | 11 " | 493·68 " |
| 3½ " | 49·98 " | 12 " | 587·52 " |
| 4 " | 65·28 " | 13 " | 689·52 " |
| 4½ " | 82·62 " | 14 " | 799·68 " |
| 5 " | 102·00 " | 15 " | 918·00 " |
| 5½ " | 123·42 " | 16 " | 1,044·48 " |
| 6 " | 146·88 " | 17 " | 1,179·12 " |
| 6½ " | 172·38 " | 18 " | 1,321·92 " |
| 7 " | 199·92 " | 19 " | 1,472·68 " |
| 7½ " | 229·50 " | 20 " | 1,632·00 " |
| 8 " | 261·12 " | 21 " | 1,799·28 " |
| 8½ " | 294 78 " | 22 " | 1,974·72 " |
| 9 " | 330·48 " | 24 " | 2,350·08 " |

By means of this table the size of the water cylinder required to discharge a given quantity of water, on a basis of a piston speed of 100 feet per minute, is at once approximately seen. Thus, to deliver 100 gallons a minute, a 5-inch cylinder would be evidently required.

It is well, however, to note that for pumps having but a short stroke, 100 feet piston speed per minute is excessive, as it causes too frequent reversal of the valves, while for long-stroke pumps this speed may be somewhat increased.

The above discharges are the theoretical ones, which are far from being attained in practice. It would be safer and more correct, therefore, to assume as a general rule that the capacity of the water cylinders should be increased by at least 20 per cent., to cover losses arising from looseness of the piston, valves, etc. The simplest way of doing this is to add 20 per cent. to the required discharge, and then find in the table the size of the water cylinder for this increased discharge. Thus, in the above case, 100 gallons × 1.20 = 120 gallons, for which by the table a 5½-inch cylinder would be necessary.

If it should be preferred to work this out directly by formula we have:

$$d^2 = \frac{1{\cdot}20G}{0{\cdot}0408p_s}, \text{ whence}$$

$$d = 5{\cdot}4\sqrt{\frac{G}{p_s}} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

and for 100 feet piston speed

$$d = 0{\cdot}54\sqrt{G} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Having thus calculated the diameter of the water cylinder which will at the given piston speed deliver the required quantity of water, we must next determine the diameter of the air cylinder, and the working pressure of the air which will raise the required quantity of water to the desired height.

The first thing to be done here is to decide upon a suitable pressure of the air. For several reasons high pressures are not recommended, the chief one being that of economy, seeing that, although a lower pressure will require a greater volume of free air, yet the proportionate and absolute cost of the power necessary to operate a larger sized air cylinder (which consumes the greater volume of free air at the lower pressure) is considerably less.

The steam or air pressure required to raise water to any given height is found by the formula.

$$P = \frac{p \times d^2}{D_a^2}$$

$$= \frac{0{\cdot}433h \times d^2}{D_a^2} \ldots\ldots\ldots\ldots\ldots (6)$$

transposing which, on the assumption that the pressure P has been previously decided upon, we have for the size of the air cylinder:

$$D_a^2 = \frac{0{\cdot}433h \times d^2}{P} \ldots\ldots\ldots\ldots\ldots (7)$$

As in the water cylinder considerable losses occur, so in the air cylinder such are inevitably met with, owing to clearance, leakage, etc. Assuming these to be 15 per cent. of the piston displacement, formula (7) becomes:

$$D_a^2 = \frac{0{\cdot}433h \times d^2 \times 1{\cdot}15}{100P}$$

$$= \frac{0{\cdot}5h \times d^2}{P} \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Taking the case already referred to, where it is required to deliver 100 gallons of water per minute, using a 5½-inch water cylinder, and assuming that the height to which it is to be raised is 80 feet, and that an air pressure of 20 pounds be used, we have by Eq. (8):

$$D_a^2 = \frac{0{\cdot}5 \times 80 \times 5{\cdot}5 \times 5.5}{20}$$

$$= 60{\cdot}5$$

and $D_a = 7{\cdot}8$ inches.

It would, therefore, be reasonable, as well as safe, in such a case to select a pump having say 8 x 6-inch cylinders and 12-inch stroke.

The next and last point, which is one of considerable interest, is the volume of equivalent free air required to do the work thus determined. For this purpose we have the formula:

$$V = \frac{0{\cdot}7854 D_a^2 \times l \times n}{1728} \times W_2$$

$$= 0{\cdot}00545 D_a^2 \times p_s \times W_2 \ldots\ldots (9)$$

in which the first expression gives the required volume of *compressed* air, while the second one, $W_2$, reduces this volume to its equivalent volume of *free air*, being a simpler form of expression for:

$$\frac{P + 14{\cdot}7}{14{\cdot}7} = 1 + 0{\cdot}068P.$$

(See "Compressed Air," Vol. II., p. 246, and also Table V., Vol. II., p. 360.)

By this formula the value of $W_2$ for 20 pounds pressure is:

$$1 + (0.068 \times 20) = 2.36$$

and inserting this value in Eq. (9) we have for the example given:

$$V = 0.00545 \times 60{\cdot}5 \times 100 \times 2{\cdot}36$$

$$= 77{\cdot}8 \text{ cubic feet.}$$

Assuming, as before, a piston speed of 100 feet per minute and adding 15 per cent. to the volume of free air required, to compensate for frictional and other resistances, we have:

$$V = 0{\cdot}63 \times D_a^2 \times W_2 \ldots\ldots\ldots (10)$$

which gives 90 cubic feet of free air required to pump 100 gallons of water per minute to a height of 80 feet, the pressure of the air being 20 pounds per square inch, the diameter of the water cylinder 5½ inches, the diameter of the air cylinder 7.8 inches, and the piston speed 100 feet per minute.

It must, of course, be understood that these formulas do not cover undue losses occasioned by friction in the delivery pipes, when these are either of too small diameter or considerable length. This point is an important one and requires equally careful consideration, so as to reduce this friction to a minimum. Space does not allow of this problem being gone into here, as to do it justice would require an article to itself.

From what precedes, it will be seen that the formulas required for solving problems relating to pumps driven by compressed air, are:

For the diameter of the water cylinder } Eq. (5).
For the diameter of the air cylinder. . } Eq. (8).
For the volume of free air.......... } Eq. (10).

*To be continued.*

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## Handling Baggage by Compressed Air.

The illustration on our cover this month will at first sight impress our readers as a very desirable and clever use of compressed air.

Mr. G. H. Wall, of Cadillac, Mich., who is connected with the Grand Rapids & Indiana Railroad, last spring built and applied the pneumatic baggage handler shown in our engraving. This device proved itself, in daily work, able to handle heavy baggage more rapidly than it could otherwise be handled, and to, moreover, do away with breakage of baggage. It consists of a very simple arrangement of air cylinder and baggage support. The cylinder rests on the threshold of the car door. The upper portion of the baggage support is semi-tubular in form and is swiveled to the cylinder; and one side of this tubular portion is cam shaped and bears against a plate placed just above the door. Thus when the support is rising it is automatically swung around by the cam action, carrying the baggage into the car. The device is operated by air drawn from the train line to a special reservoir and is handled by the train baggage man by means of suitable cocks on the inside of the car. It has a lifting capacity of 500 lbs., with 70 lbs. of air. An auxiliary

spring scale device, located at about the center of the vertical length of the baggage support, provides for weighing the baggage as it is handled. It is said that the time consumed in loading a trunk of 218 lbs. was 3½ seconds, and the time of unloading 5½ seconds. For country stations the above appliance will save many a trunk from being smashed, because only one man usually attends trains at such points, and the result of one man handling a heavy trunk is well known.

## Paint Spray.

The accompanying illustration shows the Bean pneumatic spraying machine for spraying cold water paint, whitewash or oil paints. It consists of a seamless steel cylinder 44 in. high by 8 in. diameter, with cast top and bottom, secured with four stay rods, a hand-pump attachment to furnish air independent of an air compressor or other power, a ½-in. hose and an 8-ft. bamboo rod, to which an improved spray nozzle is attached, enabling the operator to reach ceilings of ordinary height.

The Bean pneumatic coating machine is not new, but novel. It has been in use for several years and continues to give satisfaction. Those who visited the World's Fair in Chicago in the spring of 1893 marveled at the rapidity and ease with which the great buildings were coated. This machine made it possible.

To operate the machine it is first charged with air to 50 lbs. and then fed with liquid compressing the air, which forces it through the hose and nozzle upon the surface to be coated. The advantage claimed for this machine over others which have been put upon the market for similar purposes is that it is not simply a pump, but an independent air compressor, which enables one man to operate it to advantage, thus making the cost of maintenance just one half that of any other machine.

The machine is tested to 1000 and cannot get out of order. At a recent test one man coated over 23,000 sq. ft. of surface in three hours and ten minutes. The machine is arranged for double hose connection, which gives it twice the capacity, if desired. The Rice Machinery Company, 166 South Clinton Street, Chicago, are general Western agents, and in connection handle a cold water paint for use in it.

## Jets of Air.

Air at 75 pounds gage pressure will escape from a hole in the receiver at the velocity of 548 feet per second, from a short pipe at the rate of 658 feet per second. The velocity of flow varies but slightly at different pressures, only as affected by the opening, which varies the coefficient of contraction. Approximate results may be obtained in practice by using the above named velocities for any pressure between 45 and 100 pounds.

The rate of flow may be obtained from the size of the opening and the velocity given above.

The heat of compression causes the greatest loss in the use of compressed air. This is being greatly reduced by the use of compound compressors.

When the volume of air is heated 475 degrees above its initial temperature the volume, at the original pressure, will be doubled.

Air leaks in pipes are more expensive than steam leaks of the same size—about two and one-half times as great.

The compression of air, at constant temperature, follows Mariotte's law, and is inversely as the volume, the pressure being calculated in absolute units—15 pounds more than gauge pressure.

—*National Engineer*.

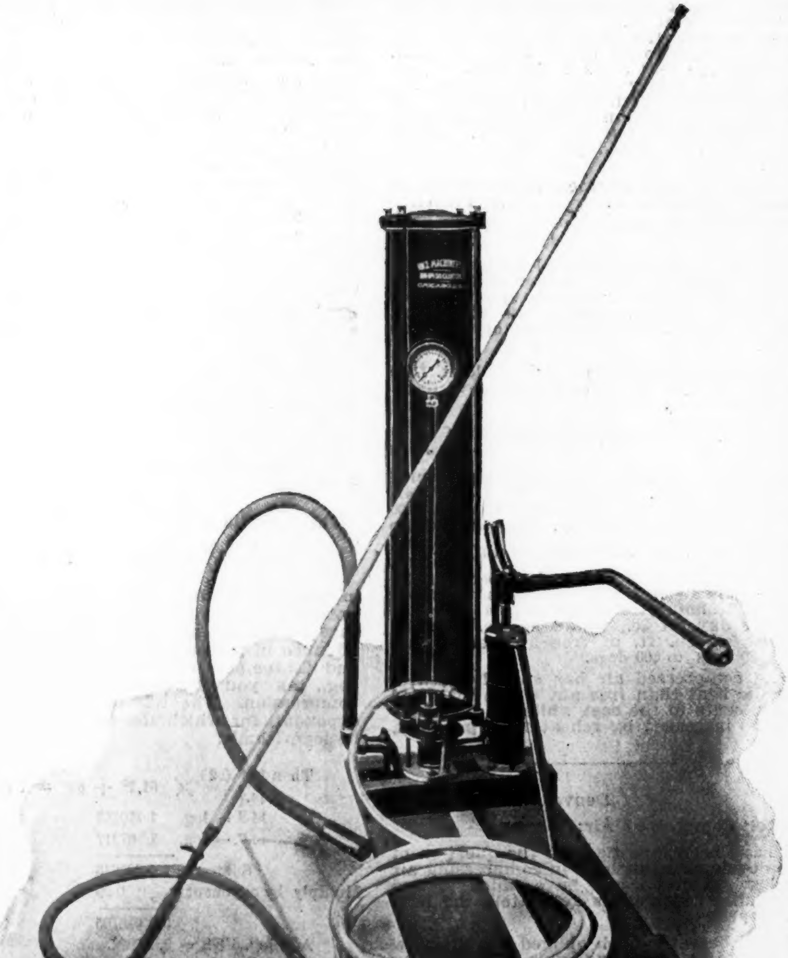
## COMMUNICATIONS.

**Under this heading will be published inquiries addressed to the Editor of COMPRESSED AIR. We wish to encourage our readers in the practice of making inquiries and expressing opinions.**

**We request that the rules governing such correspondence will be observed, viz., all communications should be written on one side of the paper only; they should be short and to the point.**

Editor Compressed Air:

I have a case where it is desired to reheat compressed air, to be used in a stationary automatic cut-off engine, consuming, perhaps, 300 to 450 cubic feet of free air per minute. We propose using oil burners of a small size and would like to know whether we can use a small-sized air re-heater, as the expense of a large size is rather too



BEAN PNEUMATIC SPRAYING MACHINE.

much. Can you give us any idea as to the number of heat units which will be necessary to raise the temperature of the air from 80 degs. to 375 or 400 degs., so that, knowing the heat units in the crude oil, we can get a pretty good idea as to the amount of oil which will be consumed. Of course, in a common open re-heater all of the heat would not be effective. About what per cent would you figure as effective?

I would greatly appreciate your views at length on this matter. PRACTICAL.

Wheeling, W. Va.

A large heater is required for this work. If you expect to heat the air to 400 degs., you might use two reheaters or a series of reheaters, though, except in stationary plants, we do not advise reheaters of large sizes.

Four hundred and fifty (450) cubic ft. free air per minute, to be raised from 80 degs. to 400 degs. F.,

$$\frac{450\ \text{c.}'}{13} = 34\tfrac{3}{4}\ \text{lbs.} \times .2377 = 8.26$$

heat units per degree rise in temperature; 400—80=320 degs. required; 320 x 3.26=2643 heat units per minute using oil=to 20,000 heat units per pound, say, deducting waste heat=14,000 heat units are available $\frac{2643}{14,000}$ =.188 of a pound of oil required per minute, 11.28 pounds per hour, or 112.8 pounds per day of 10 hours, or about 16 gallons crude oil per day, at 3c., would be 48c. price to reheat 450 cu. ft. of free air per minute from 80 degs. to 400 degs.

The compressed air has slightly greater specific heat than free air, which may add a few cents to the cost while the efficiency will be increased by reheating 44 per cent.

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Denver, Nov. 21, 1898.

Editor Compressed Air:

I have been investigating the question of the development of heat in compressing air at low pressures, and have failed to find any table which gives accurately the heat developed.

I will be very much obliged if you know of any table which will give the following information. If you will send it to me or advise me where I can get it, or if you can give me the figures in this particular item, I will be very much indebted to you.

What I want to know is this: Given 10 cubic ft. of air at 32 degs. F. and atmospheric pressure, how much pressure will be necessary to raise the temperature of this air to 33 degs., and how much reduction in the volume of the 10 ft. will there be at this pressure?

Thanking you in advance for any trouble you may take in this matter, I am,

Yours very truly,

MINING ENGINEER.

The diagram shown on page 10 of "Compressed Air Production," and also in "Compressed Air," Vol. i, No. 3, page 7, shows the relative difference in volumes, pressures and temperatures during the compression of air. This diagram does not give the difference as close as 1 deg., but it may serve your purpose; if not, we would refer you to Shones' tables, printed in the "Scientific American Supplement" No. 279 and prepared by Isaac Shone, C. E. We know of no tables closer than these, which are for differences of one pound pressure. They may be readily interpolated for fractions of a pound equal to 1 deg. rise in temperature. The only formula applicable to the case is that of Dubois and Röntgen, which was used by Shone in computing the tables published in the "Scientific American Supplement" No. 279, to which we have referred. The formula is for difference of temperature due to compression by compression or volume differences. It would have to be inverted for differences of pressure or volume due to temperature. The inversion is not stated in the books, but can be done with some experimental computation.

The formula is:

$$\frac{p}{P}^{0.29} \times 461.2 + T = t,$$

in which p is atmospheric pressure=14.7; p=pressure of compression, which for your case we assume as 14.8, or one-tenth pound advance in pressure; 461.2=absolute zero F. and T=temperature above zero F., or 32 deg., as you suggest; t=temperature of compression. The 0.29 is the logarithmic exponent, for which the computation must be logarithmic.

Then $\frac{14.8}{14.7}^{0.29} \times 461.2^\circ + 32^\circ = t$ and

| | |
|---|---|
| 14 8 — log. | 1.170262 |
| 14.7 — log. | 1.167317 |
| Subtract | 0.002945 |
| Multiply by exponent | 0 29 |
| | 0.00085405 |
| Add log. 493.2 — | 2.693023 |
| | 2.69387705 |
| Log. number | 494.19 |
| Subtract | 493.20 |
| | .99° rise in temperature. |

You will notice by an examination of Shone's table that an interpolation can be made that will answer all practical purposes for low pressures, and with care may be made for any pressure within the scope of that table. For low pressures 1-10 of a pound pressure, or volume, very nearly corresponds with 1 deg. F. difference of temperature.

## ALPHABETICAL LIST OF PNEUMATIC INVENTIONS.

For which United States patents have been granted. Prepared for COMPRESSED AIR from official records by GRAFTON L. MCGILL.

| APPLIANCE. | NAME OF INVENTOR. | DATE OF ISSUE. | No. |
|---|---|---|---|
| Air Brake | Eames | May 10, 1881 | 241,323 |
| " | " | May 10, 1881 | 241,325 |
| " | Easton | Dec. 7, 1886 | 354,014 |
| " | Edwards | Oct. 23, 1894 | 527,838 |
| " | Eldridge | Oct. 9, 1894 | 527,327 |
| " | Erdody | Dec. 12, 1893 | 510,594 |
| " | Fahrney | Nov. 1, 1892 | 485,182 |
| " | Feruley et al. | Jan. 21, 1896 | 553,498 |
| " | Fish | Nov. 23, 1897 | 593,996 |
| " | Flad | April 8, 1884 | 296,546 |
| " | " | Nov. 4, 1884 | 307,535 |
| " | " | Nov. 4, 1884 | 307,536 |
| " | Fogelberg | May 28, 1872 | 127,332 |
| " | Ford | Oct. 31, 1882 | 266,684 |
| " | " | March 27, 1883 | Reissue 10,298 |
| " | Fox | Dec. 18, 1894 | 530,937 |
| " | " | Dec. 18, 1894 | 530,938 |
| " | " | Dec. 18, 1894 | 530,939 |
| " | French | Jan. 29, 1895 | 533,286 |
| " | Genett | March 24, 1896 | 556,815 |
| " | Goode | Nov. 30, 1886 | 353,446 |
| " | Glenn | Nov. 9, 1880 | 234,179 |
| " | Glass | Oct. 20, 1896 | 569,915 |
| " | Graebing | Oct. 20, 1896 | 569,823 |
| " | Gray | Feb. 22, 1898 | 599,421 |
| " | Green et al | Dec. 11, 1877 | 198,015 |
| " | Green | Dec. 30, 1884 | 309,845 |
| " | Guels | June 19, 1888 | 384,686 |
| " | " | June 19, 18 8 | 384,687 |
| " | " | April 15, 1890 | Reissue 11,070 |
| " | Guillemet | Sept. 30, 1890 | 437,300 |
| " | " | Sept. 6, 1892 | 482,040 |
| " | " | Nov. 10, 1896 | 571,115 |
| " | " | Nov. 10, 1896 | 571,116 |
| " | Gunckel | May 11, 1897 | 582,391 |
| " | " | March 29, 1898 | 601,253 |
| " | Haberkorn | Feb. 2, 1886 | 335,446 |
| " | " | March 5, 1889 | 398,829 |
| " | " | Oct. 22, 1889 | 413,253 |
| " | " | Dec. 18, 1894 | 531,181 |
| " | Hanscom | August 30, 1887 | 369,057 |
| " | " | Oct. 10, 1882 | 265,671 |
| " | " | Sept. 22, 1885 | 326,646 |
| " | Hall | August 17, 1880 | 231,311 |
| " | " | Dec. 29, 1896 | 574,062 |
| " | Hamar et al | March 15, 1898 | 600 641 |
| " | Hanney | June 14, 1892 | 476,880 |
| " | Harris | Dec. 16, 1890 | 442,621 |
| " | " | April 5, 1892 | 472,190 |
| " | " | Feb. 20, 1894 | 515,220 |
| " | " | March 13, 1894 | 516,202 |

ALPHABETICAL LIST OF PNEUMATIC INVENTIONS.—*Cont.*

| APPLIANCE. | NAME OF INVENTOR. | DATE OF ISSUE. | NO. |
|---|---|---|---|
| Air Brake | Harris | August 6, 1895 | 544,253 |
| " | " | Nov. 17, 1896 | 571,662 |
| " | " | Oct. 1, 1895 | 547,253 |
| " | Harvey | Feb. 21, 1888 | 378,365 |
| " | Hayden | August 30, 1892 | 481,651 |
| " | " | Dec. 5, 1893 | 509,898 |
| " | Herder | April 14, 1896 | 558,174 |
| " | Herbert | Nov. 24, 1896 | 572,009 |
| " | High | March 3, 1896 | 555,809 |
| " | Higgins | August 8, 1893 | 503,083 |
| " | Hinckley | Nov. 14, 1893 | 508,421 |
| " | Hogan | April 26, 1892 | 473,839 |
| " | " | Sept. 6, 1892 | 482,058 |
| " | " | March 3, 1891 | 447,731 |
| " | " | July 29, 1890 | 433,127 |
| " | " | August 5, 1890 | 433,594 |
| " | " | August 5, 1890 | 433,595 |
| " | " | Jan. 5, 1897 | 574,866 |
| " | " | Sept. 17, 1895 | 546,448 |
| " | " | Sept. 17, 1895 | 546,449 |
| " | " | Dec. 17, 1895 | 551,440 |
| " | " | Dec. 24, 1895 | 551,767 |
| " | Hollerith | Jan. 12, 1886 | 334,020 |
| " | " | Jan. 12, 1886 | 334,021 |
| " | " | Jan. 12, 1886 | 334,022 |
| " | Holleman | June 25, 1889 | 405,705 |
| " | Hopper | June 10, 1890 | 430,024 |
| " | " | Sept. 1, 1891 | 458,626 |
| " | " | July 14, 1885 | 321,971 |
| " | Howe et al | Sept. 8, 1896 | 567,476 |
| " | Humbert et al. | May 21, 1895 | 539,430 |
| " | Hunt | August 27, 1895 | 545,295 |
| " | " | May 4, 1897 | 581,912 |
| " | " | Nov. 13, 1894 | 529,270 |

## PATENTS GRANTED OCT., 1898.

Specially prepared for COMPRESSED AIR from the Patent Office files by Grafton L. McGill, Washington. D. C.

613,692—Air Compressor Governor.—Libby & Potter, Schenectady, N. Y., assignors to the General Electric Company.

The switch mechanism is actuated by a piston and cylinder. A valve is located between said cylinder and an auxiliary cylinder, the latter supporting a spring-actuated pin, which opens and closes the valve. A spring tends to maintain the auxiliary piston in its normal position, while an exhaust valve, connecting with the switch-actuating cylinder, is normally closed by a spring-pressed device and opened by means connected with the auxiliary piston.

614,275—Apparatus for Heating and Agitating Air.—E. F. Porter, Boston, Mass., assignor to the Bay State Electric Heat & Light Company, Jersey City, N. J.

A series of plates are heated by electricity, or otherwise, and are so moved, relatively to each other, as to agitate the surrounding air. Spring mechanism is provided to regulate the distance between the plates.

614,992—Air Engine.—Michael Schmidt, Cramer's Hill, N. J.

This invention contemplates the employment of an airmotor on a bicycle. The wheel is preferably of the "drop frame" construction and has an air chest on each side of the frame, connected with the bottom bend thereof by a pipe, having a shut-off cock therein. Eccentrics on the wheel shaft actuate the valves in the air chest, while air cylinders, one on each side of the frame, are provided with air pumps, the latter having plungers, on which the treadles are located.

### Bell Ringer.

Mr. E. M. Crandall, foreman of the St. Joseph shops of the K. C., St. J. & C. B. R. R., has designed a locomotive bell ringer to be operated by compressed air. Several of them are now in use on the locomotives of that road.